Fatigue Management for Military Operations

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Definition of fatigue

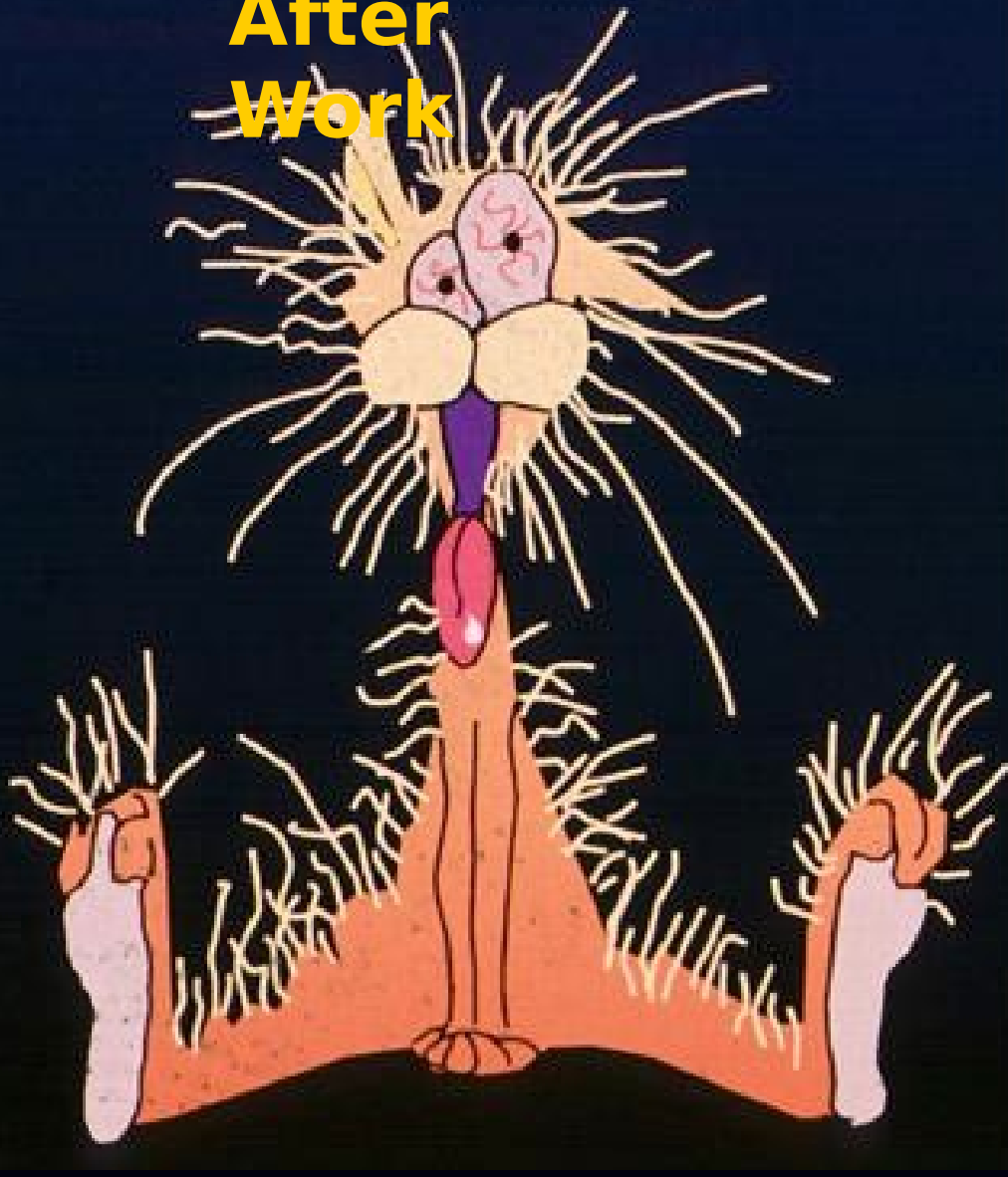
- Fatigue is the state of tiredness associated with prolonged work, and/or prolonged wakefulness.
- Sleep deprivation and circadian factors are major components of the fatigue equation.
- Fatigue is an internal state that affects both physiological activity and subjective feelings.
- The terms “fatigue” and “sleepiness” are often used interchangeably.

Measuring fatigue

- Unfortunately, there are no biochemical markers for fatigue.
- Thus, there isn’t a breathalyzer for fatigue/sleepiness.
- Often we must rely on subjective impressions of ourselves or others to know how fatigued we are.

Before Work

After Work



Fatigue is a big problem

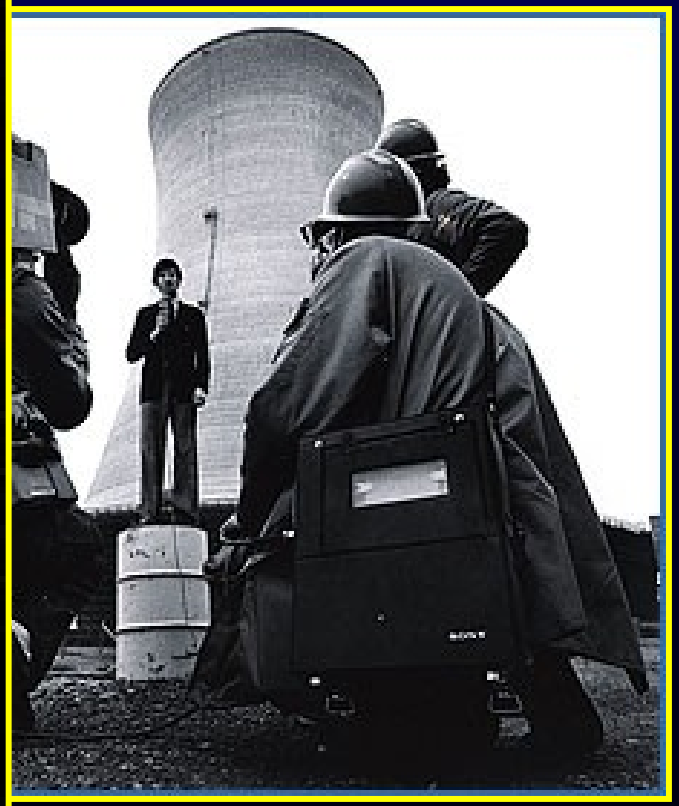
- The fact that fatigue cannot be directly measured doesn't mean it isn't a serious concern.

- The sleep loss and circadian disruptions caused by so-called "24-7" operations often lead to fatigue levels that have dire consequences.

Grounding of the Exxon Valdez

Third mate misses light and buoy marking shore and crashes into reef after hours of duty without sleep. 11 million barrels of oil spilled.

Near Meltdown at Three Mile Island



Night shift misdiagnoses problems with emergency feedwater, heating reactor to 4,300 degrees. Radioactive material vented to atmosphere.

Crash of American Airlines Flight 1420

Experienced pilot lands in severe weather (75 mph gusts) after 13 hours on duty. Nine killed.

Fatigue costs everyone

- Approximately 7 percent of reports in the Aviation Safety Reporting System are fatigue related.
- Fatigue costs $54 million annually in Air Force Class A mishaps alone.
- NHTSA attributes 100,000 accidents, 1,500 fatalities, 71,000 injuries, and $12.5 billion a year to fatigue.
- The National Sleep Foundation estimates sleepy personnel cost employers $18 billion annually in lost productivity.

Why is fatigue a growing problem throughout society?

- Since 1883, the electric light changed night into day, extending work time.
- This led to reduced sleep time (in the past century Americans have reduced their sleep time by 20%, down to less than 7 hrs a night).
- In the 1950's the advent of night vision technology made the battlefield a 24/7 operation.
- Over 25 million people now routinely engage in shift work (and many are in the military).
- Transportation improvements have enabled the crossing of 1 time zone *per hour* rather than 1 time zone *per day*.

Fatigue degrades performance and mental abilities

- Accuracy and timing degrade
- Lower standards of performance become acceptable
- Attentional resources are difficult to divide
- The ability to integrate information is lost
- Everything becomes more difficult to perform
- Social interactions decline
- The ability to logically reason is impaired
- Attention wanes
- Attitude and mood deteriorates
- Involuntary lapses into sleep begin to occur

The Basic Causes of Fatigue

The basic mechanisms

- **Fatigue levels are primarily a function of two factors:**
  - **the circadian pacemaker (body clock), which makes fatigue worse at some times than at others**

    and
  - **the amount of time since the last sleep period, which is also called the homeostatic mechanism**
- **The quality of sleep prior to the period of performance also is important.**

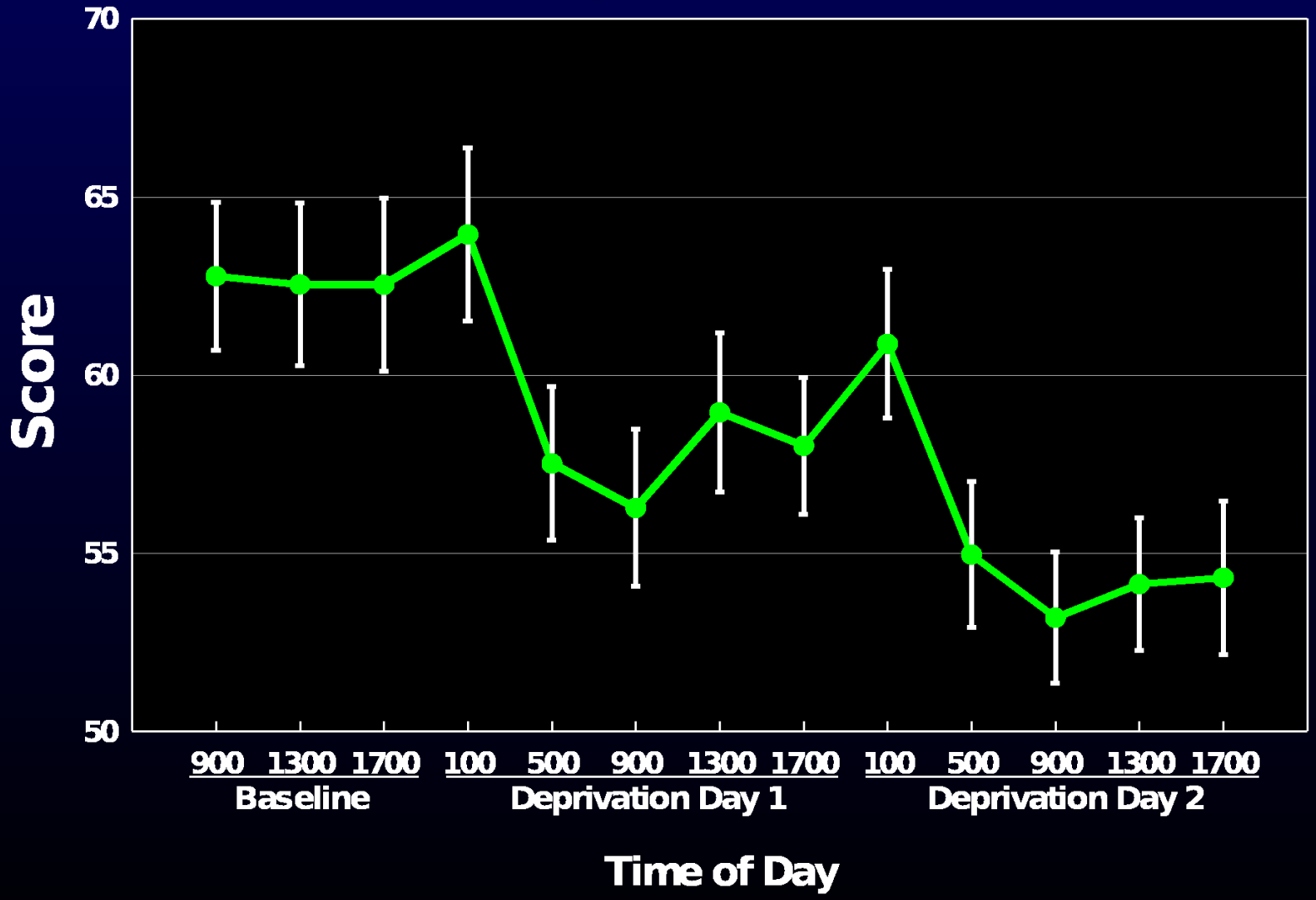
The circadian mechanism

- Time of day (according to the body's clock) is a crucial determinant of the level of alertness.
- Maximum sleepiness normally occurs during the predawn hours (between 0200 and 0500).
- But there is also a brief increase in sleepiness during the early afternoon (the post-lunch dip).
- After crossing multiple time zones, the normal period of predawn fatigue (body-clock time) may end up in the middle of the day (destination time).

The homeostatic mechanism

- Time since the last sleep episode is the most important determinant of the homeostatic part of the fatigue equation.
- Homeostatically-based sleepiness (fatigue) is low right after sleep, but increases as time passes.
- At bedtime, sleepiness is very high because the homeostatic drive for sleep is high.
- The homeostatic drive dissipates exponentially when sleep occurs.
- However, if sleep architecture is disturbed, the drive will not fully recover, even after long sleeps.
- Also, sleep restriction progressively increases the homeostatic drive for sleep.

Circadian factors and sleep loss combine to degrade performance



Circadian rhythms

- Most biological and psychological processes naturally vary on a 24-hour cycle:
  - Body temperature
  - Hormone levels
  - Alertness levels
- Light is the primary cue that makes these rhythms consistent.
- However, even people deprived of light exposure maintain a rhythm about 25 hours in length.

Disturbances of circadian rhythms

- There are hundreds of processes that run in tune based on the body clock.
- However, if something disturbs the clock, these processes fall “out of sync.”
- The most common circadian problems are:
  - **Jet lag** (the body’s clock is out of sync with external time cues because of travel)
  - **Shift lag** (the body’s clock is out of sync with external time cues because of work demands)

The problem of jet lag

- Rapid transportation from one time zone to another causes a desynchrony between the body clock and the environmental time cues.
- A time change of 3 hours or more will lead to significant jet lag.
- Jet-lag is usually short-lived and the body readjusts relatively quickly (compared to shift-work).
- It can take 1 to 2 weeks to readapt after a 5-8-hour time change.
- The rule of thumb indicates that, *at best*, 1 day of adjustment is required for each 1 hour of time change.
- It is easier to readjust after an east-west flight than after a west-east flight.

The problem of shift lag

- Shift work with night duty calls for alertness when the body clock indicates it's time for sleep, and sleep when the body is programmed to be awake.
- Night workers are sleepier at work and their productivity suffers, in part because they have shorter sleep compared to day or evening workers.
- Conflicts between schedule demands and social, lighting, and other time cues prevent full adjustment.
- Most research indicates that workers never truly adjust to night shift.
- Rotating shifts are generally seen as more problematic than fixed shifts.

fatigue factors in Sustained Operations

- Around-the-clock work and long-range deployments produce uncomfortable physical symptoms and fatigue from circadian factors.
- This circadian-related fatigue is exacerbated by sleep difficulties that increase the homeostatic sleep drive.

Sleep Duration (Hours)

Out-of-Phase Sleep Is not as long or as restful as Normal Sleep

- The sleep cycle is disrupted by schedule changes as well as other factors.
- These disruptions produce sleep-architecture disturbances, and outright problems with insomnia.
- The lack of restful sleep creates fatigue the next day.
- Daytime sleep characteristics are different from those of nighttime sleep (the same applies to sleep after time-zone changes):
  - REM sleep onset generally occurs earlier in the sleep period.
  - Slow-wave sleep generally occurs later.

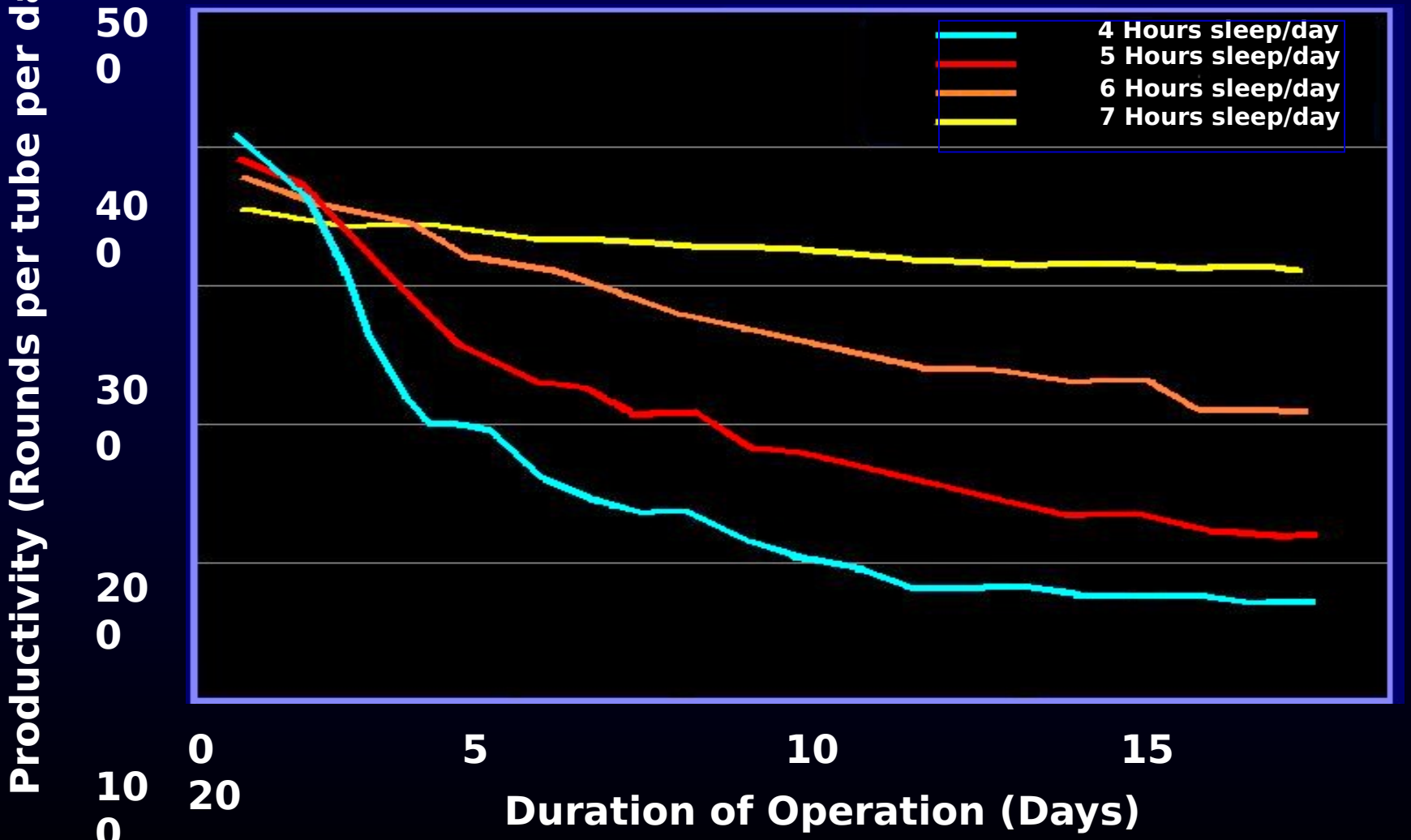
Sleep problems

- In the absence of *sleep disorders, long work hours, rotating work schedules, deployment-related jet lag, and inadequate sleep opportunities*, there are other sleep-related reasons for excessive on-the-job sleepiness.
- Many of these can be effectively managed or controlled altogether. These include:
  - Intentional sleep restriction
  - Poor sleep habits
  - Or others

Intentional sleep restriction

- Many personnel treat sleep as an option rather than a requirement.
- Even when there is no operational requirement for sleep restriction, people sacrifice their own sleep.
- A great deal of on-the-job sleepiness results simply from going to bed too late and getting up too early.
- The average adult in the U.S. sleeps only 6 hours and 54 minutes per night during work weeks.
- This is well below the recommended amount of nightly sleep which is 8 full hours!

Effects of sleep restriction on artillery company performance



Belenky et al., 1994

Symptoms and solutions for intentional sleep restriction

- ***Symptoms:***
  - **Despite the lack of an identified sleep disorder.**
  - **Problems with going to sleep while watching TV, attending meetings, conversing with others, working, or driving *or even flying.***
- ***Solutions:***
  - **Evaluate the amount of time spent asleep each night.**
  - **Gradually lengthen the sleep period until daytime sleepiness subsides.**
  - **Ignore what other people say about how much sleep is necessary (*individual sleep needs differ quite a bit).***

Poor sleep hygiene

- For many people, falling asleep and sleeping well come naturally.
- However, many personnel defeat these good natural tendencies with lifestyle and dietary habits that cause insomnia.
- Generally, poor sleep habits involve behaviors, diets, substances, or environmental factors (light, noise, etc.) that are not conducive to restful sleep.
- Insomnia from bad sleep habits can be eliminated by consciously working on better sleep hygiene.

Specific recommendations for good sleep habits

- As much as possible, stick to a consistent wake-up and bedtime every day of the week.
- Use the sleeping area only for sleep.
- Resolve worries outside of the sleep area.
- Engage in a consistent “getting ready for bed” routine as often as possible.
- Establish an exercise routine and stick to it.
- Make every effort to create a quiet and comfortable sleep environment (as much as possible).
- Don’t consume caffeine within 4 hours of bedtime.
- Don’t use alcohol as a sleep aid.
- Don’t smoke cigarettes immediately before bed.

The bottom line

- The best way to avoid fatigue on the job is to get enough sleep before reporting for duty.
- Both leaders and personnel should make sleep a priority when schedules are made.
- Few other strategies will do more to avoid fatigue and improve alertness, performance, and well being.
- There is no substitute for adequate sleep on a day-to-day basis!

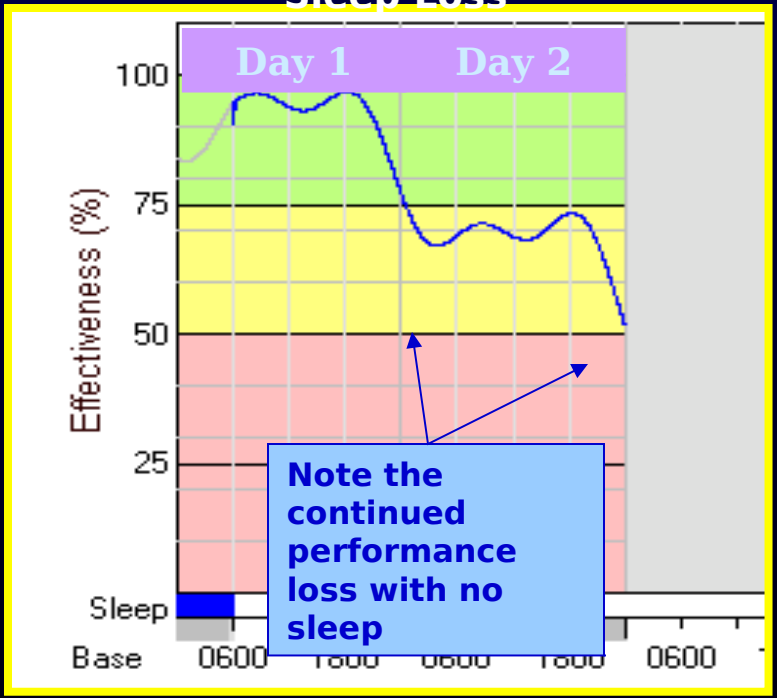
Fatigue Countermeasures

Develop proper shift schedules

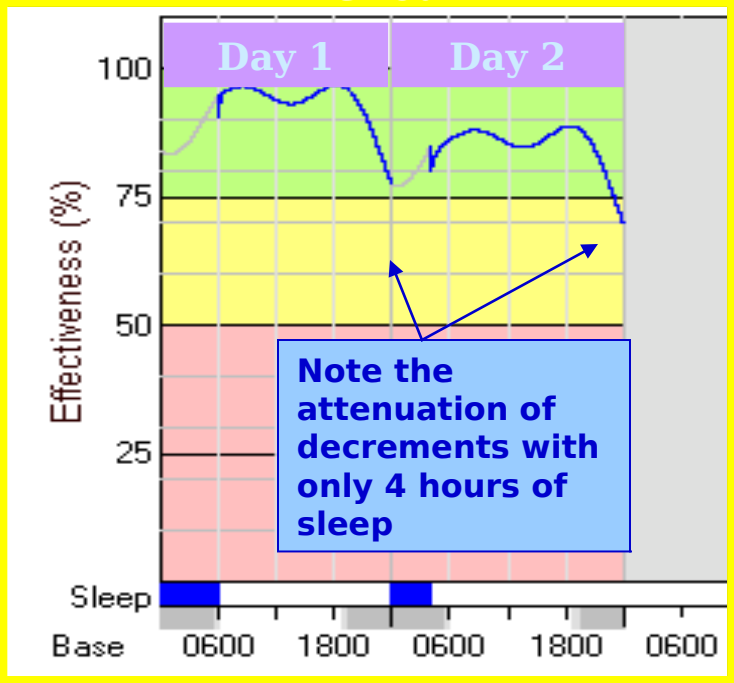
- Subjective complaints of sleepiness, fatigue, and poor performance are big problems for personnel working night shift.
- Thus, make efforts to:
  - Reduce mental demands on personnel working nights.
  - If possible, avoid long shifts since fatigue at night is already problematic.
  - If possible, schedule off-duty time with the aim of ensuring 8 hours or sleep per day.
  - If using split shifts, schedule off-duty times for periods when sleep is naturally easy to obtain.
  - Ensure clockwise transitions when changing work schedules.
- Remember, most people never really adjust to night work.

Computerized scheduling tools can estimate risky work times and help schedule optimal work/rest periods

Performance Decrement with Sleep Loss



Improvement with a Short Sleep Period



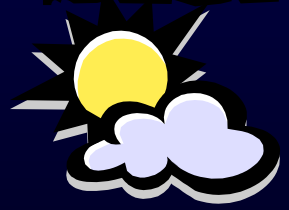
For information contact: Major Doan at brandon.doan@brooks.af.mil

When changing to new work shifts, use light to reset the body clock

- Light of 1000 lux *(fairly bright artificial light)* is known to reset the body clock.
- However, even intensities as low as 150 lux *(room lighting)* have some effect.
- A 2- to 3-hour light pulse is needed.
- The placement of light will determine which way the clock shifts and the amount of the shift.
  - Light in the morning advances the rhythm
  - Light in the evening delays the rhythm
- At best light can shift the clock 3 hours per day.

Intensity levels of various light sources

Sunny Day -- 100,000 lux



Cloudy day -- 10,000 lux

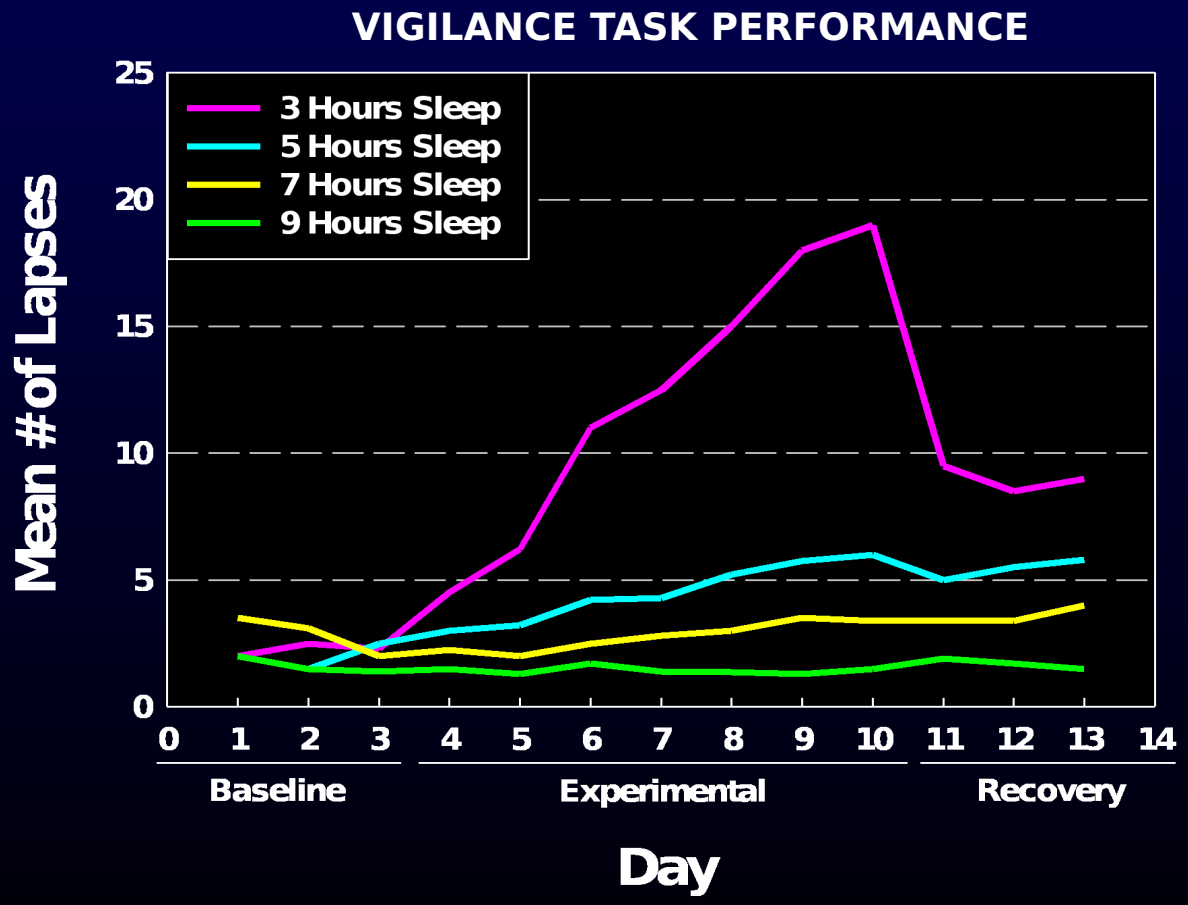
Bright artificial light -- 2,000 lux

Ordinary indoor light -- 200 lux

Sufficient daily sleep is essential for avoiding fatigue-related problems

- **Sleep restriction severely degrades performance.**
- **When sleep is less than *5 hours per night*, fatigue becomes a problem almost immediately.**
- **When sleep is cut to less than *4 hours per night*, uncontrolled sleep attacks occur.**
- ***Seven hours per night* is the minimum requirement.**
  - ***However, the average requirement is 8 h, and some people will need more.***
  - **Personnel will know they've found the right amount when it's easy to stay alert even during boring and/or sedentary tasks.**
- **Personnel cannot train themselves to get by on less sleep!**

Chronic sleep restriction has its price



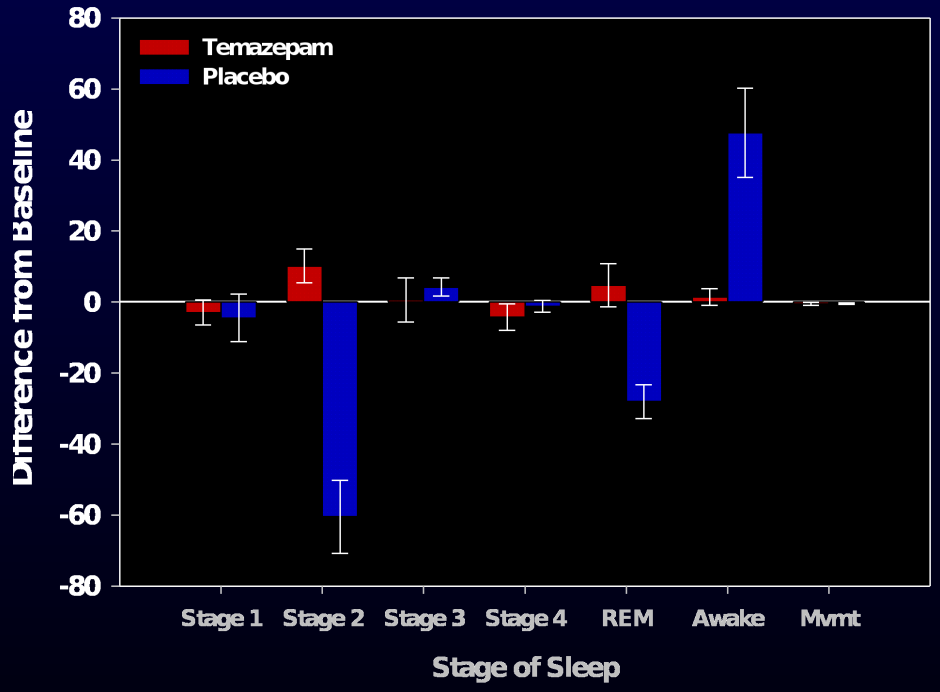
Balkin et al., 2000

Consider hypnotics when circadian factors make sleep difficult

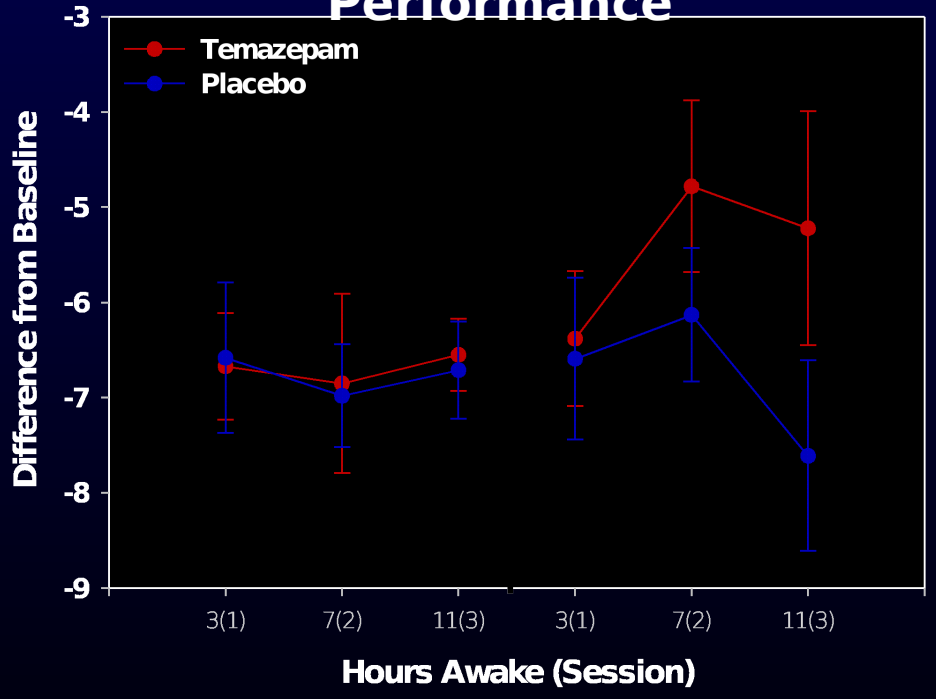
- Both temazepam (Restoril®) and zolpidem (Ambien®) can effectively promote “out of phase” sleep.
- Studies of temazepam have shown that it can significantly improve daytime sleep and nighttime performance (in shiftwork operations).
- The standard dose of Restoril® is 30 mg before bedtime.
- Zolpidem (10 mg) also can improve short periods of “out of phase” sleep. It is better for naps.
- Both of these medications can minimize the impact of shift lag and jet lag.

sleep and subsequent nighttime performance

Daytime Sleep Parameters



Nighttime Simulator Performance

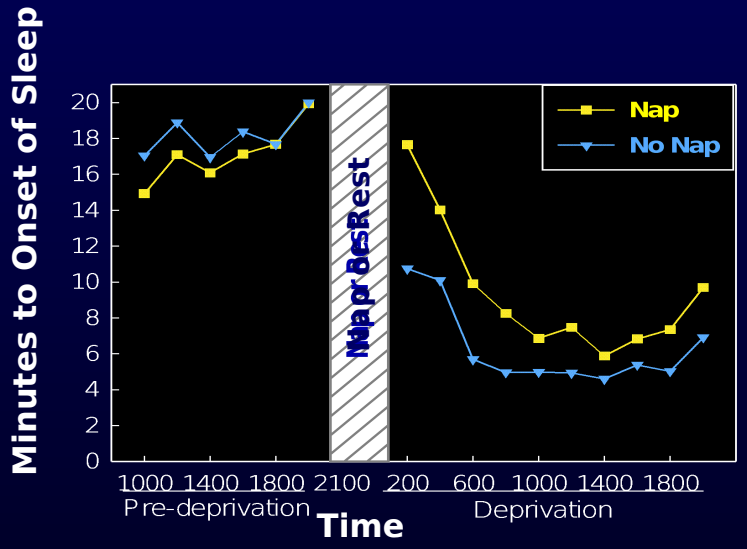


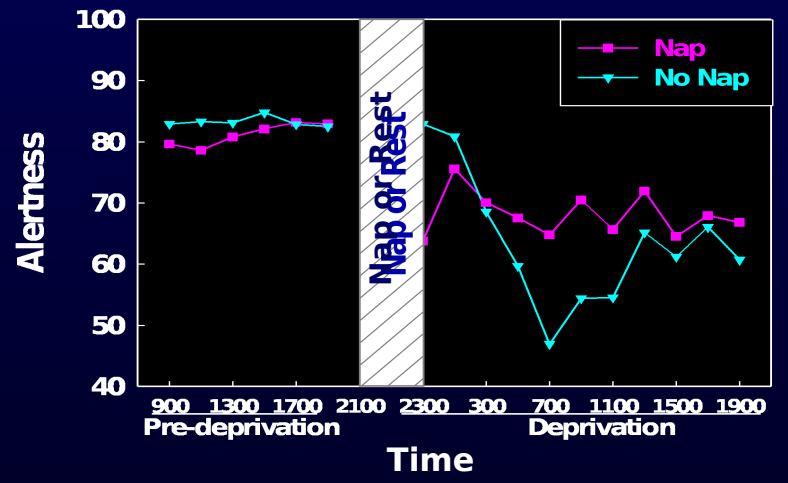
From Caldwell et al., 2003

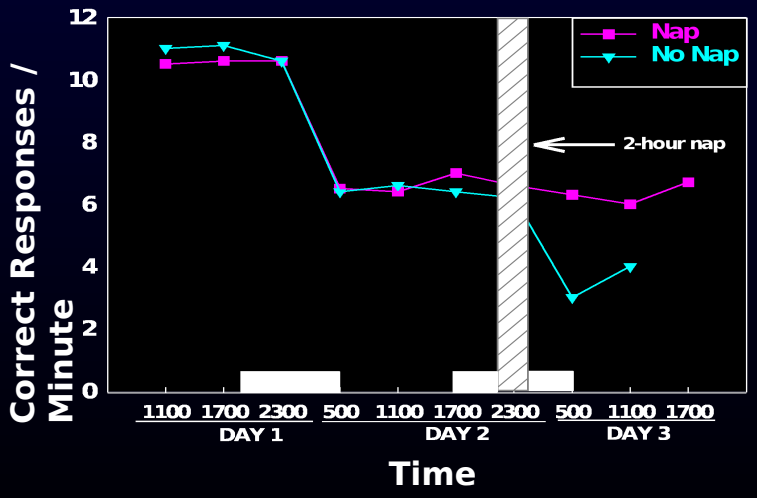
Strategic naps are very effective

- Naps can be used prophylactically to maintain performance during a subsequent period of prolonged wakefulness.
- Naps also can be used to arrest the performance decline that occurs from sleep deprivation.
- The basic principle behind napping is that it reduces the length of time between the last sleep period and the subsequent performance period.
- Naps have been proven to maintain or improve mood, performance, and alertness in a variety of situations.

Naps can bridge the gap between consolidated sleep periods







Caldwell et al., 1998; Angus et al., 1992

Points to consider when using naps in operational settings

- **A quiet, dark, cool environment is the most conducive to sleep**
  - ***Mask out noise with foam ear plugs***
  - ***Minimize light exposure with a sleep mask***
- **It is easier to sleep at some times of the day than others**
  - ***Between 0100-0500 is the best time***
  - ***But afternoon naps between 1400-1600 are a good alternative***
- **It is better to place naps early in the period of continuous wakefulness**
  - ***It is easier to attenuate declines in alertness than it is to restore alertness that has already declined***
- **The longer the nap the better its effects**
  - ***There is a dose-response relationship between sleep and alertness***
- **However, be sure to allow time for sleep inertia to dissipate**

Sleep medications can promote naps in non-sleep-conducive settings

- If a napping opportunity becomes available…

but

- The nap occurs at a non-sleep-conducive time,

then

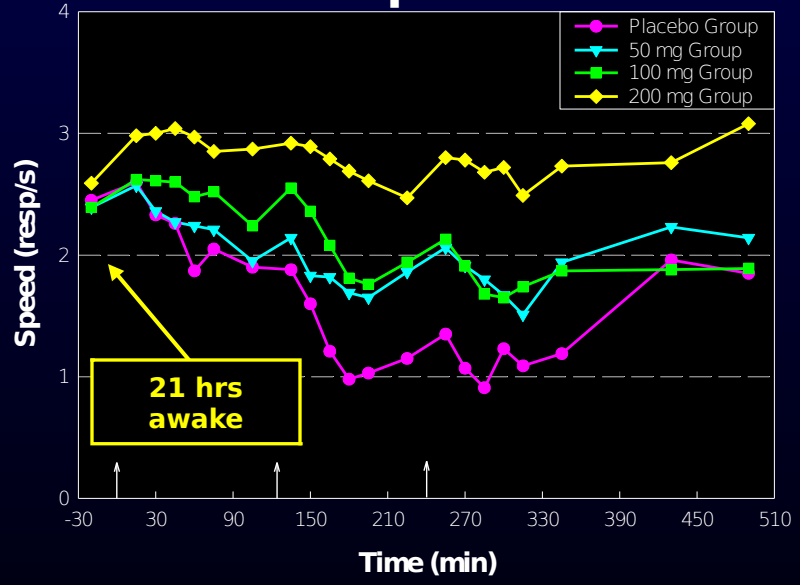
- Consider zolpidem (Ambien®) or zaleplon (Sonata®).
  - Zolpidem has a half life of only 2.5 hours.
  - Zaleplon has a half life of only 1 hour.
- Both are good choices for initiating and maintaining short periods of sleep (naps)

Consider the use of caffeine

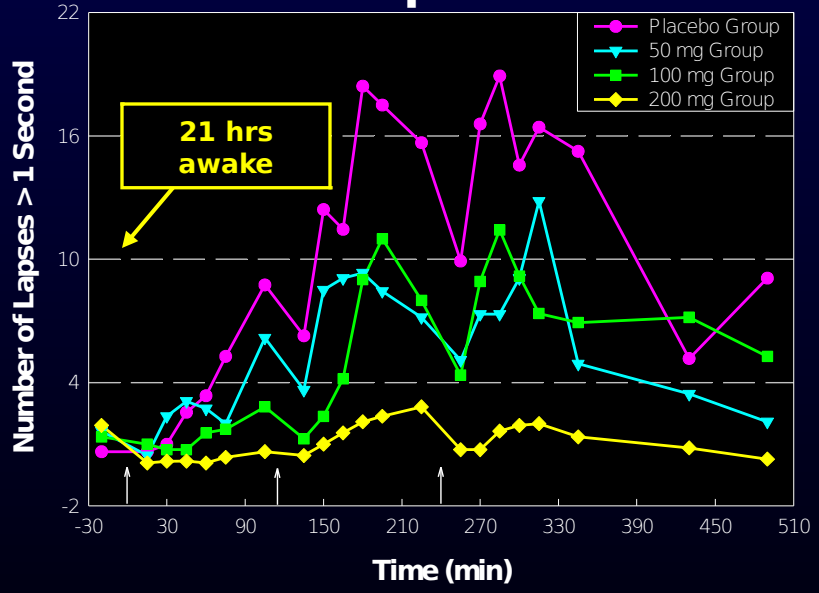
- When natural fatigue countermeasures are impossible, caffeine is an effective alternative.
- Studies have shown that caffeine significantly improves both alertness (measured by MWTs) and performance (measured by the PVT, etc.).
- Doses ranging from 200-600 mg are particularly effective in people who do not normally use caffeine.
  - 1 cup coffee= 100 mg 1 cup tea= 40 mg
  - 1 Coke= 31 mg 1 Excedrin= 65 mg
  - 1 NoDoze= 200 mg
- However, caffeine must be used judiciously
  - It is best to take caffeine only right before you need it!

Caffeine can attenuate the impact of sleep deprivation

Psychomotor Vigilance Speed



Psychomotor Vigilance Lapses



The caffeine here was administered in the form of caffeine gum.

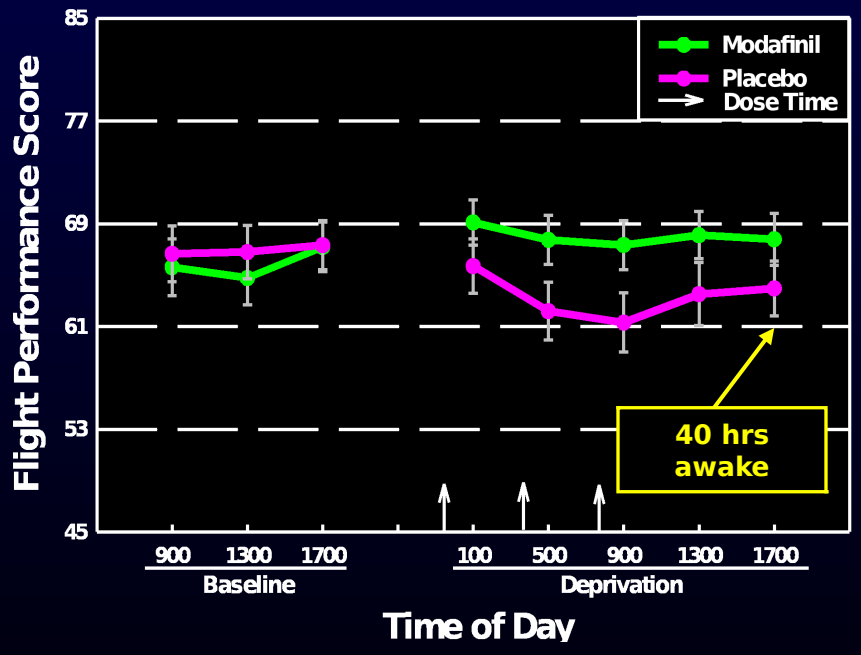
From Kamimori et al., 2002

Modafinil may soon be an alternative for some military personnel

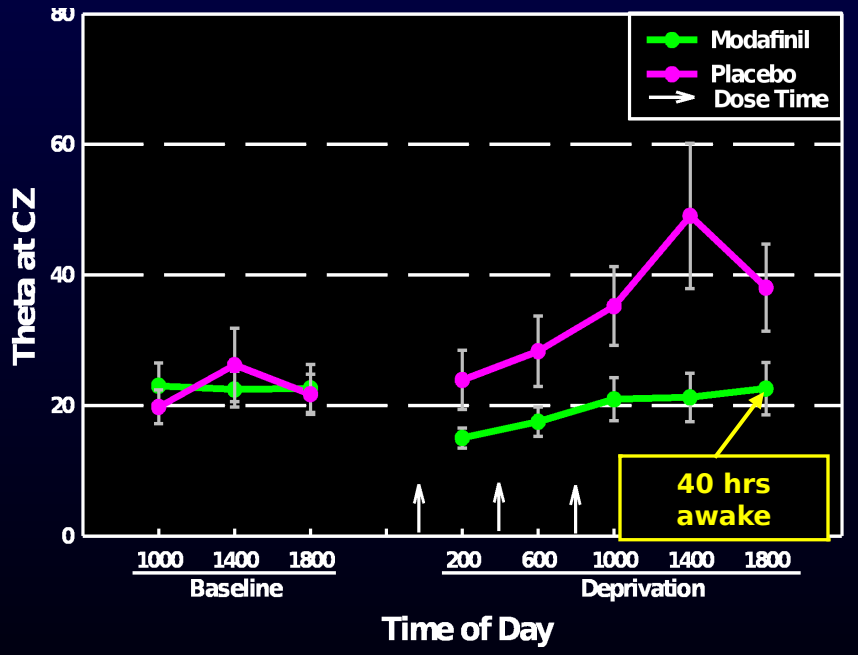
- Modafinil (Provigil®) has been FDA approved for the treatment of narcolepsy and shift-worker sleepiness.
- Studies of modafinil in normals have shown that it significantly improves flight performance, cognitive performance, and alertness.
- Doses ranging from 100-400 mg per day are effective *(currently, 100-200 mg every 8 hours is recommended).*
- Studies are underway to determine whether modafinil should be used by fighter pilots.
- At present, modafinil is only approved for use in the certain Air Force bomber operations.

Modafinil can sustain performance despite significant sleep loss

Flight Performance



Slow-wave EEG



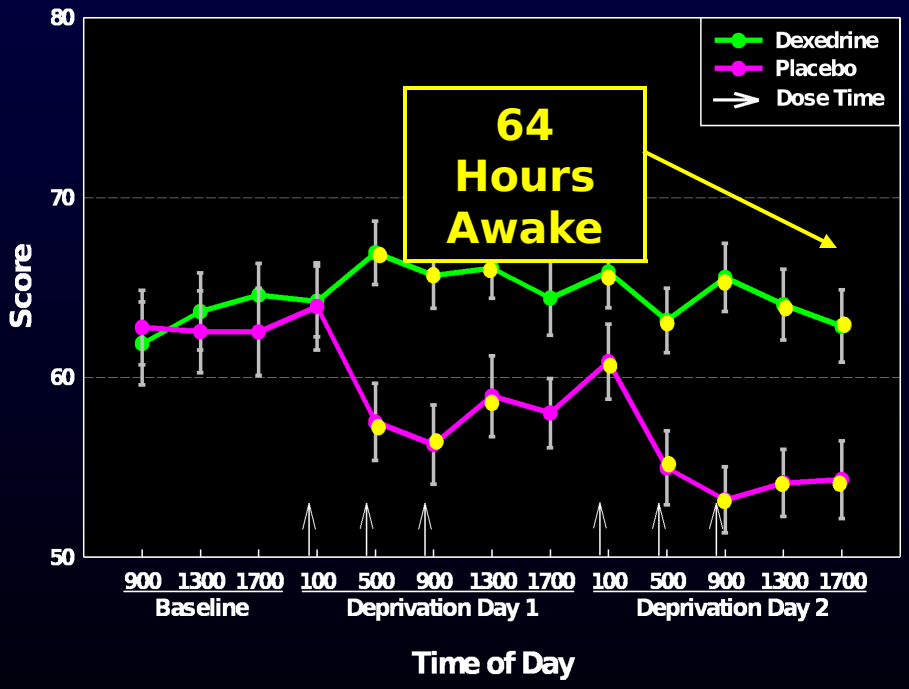
From Caldwell et al., 2000

Dexedrine® is an established fatigue countermeasure

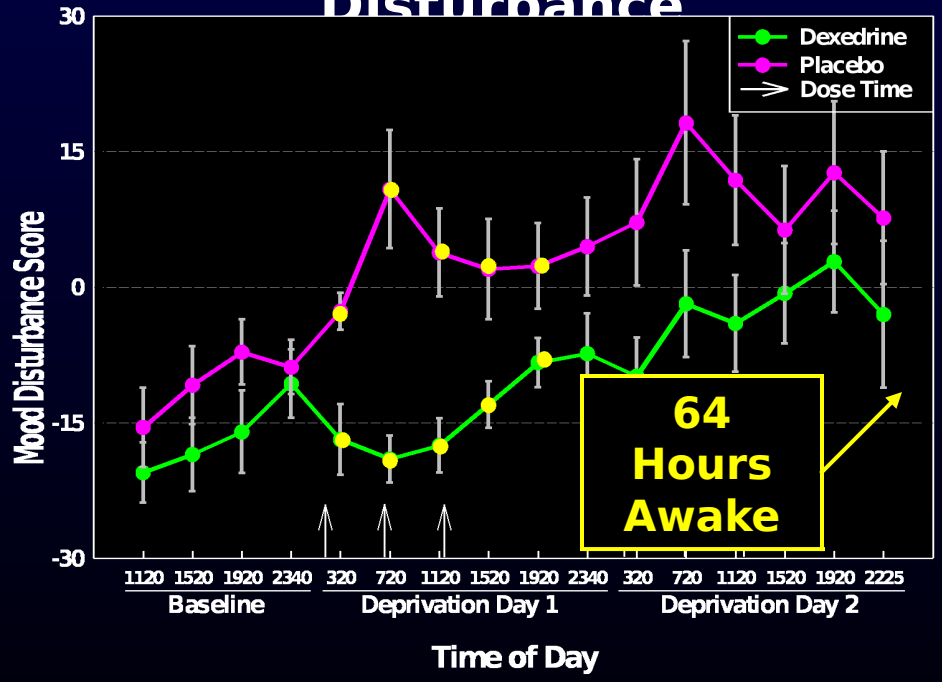
- Dextroamphetamine has been FDA approved for the treatment of narcolepsy and ADHD.
- Years of study show that amphetamines significantly improve the mood, cognitive performance, and alertness of fatigued people.
- Doses ranging from 5-20 mg, up to 60 mg per day, are safe *(currently, repeated 10 mg doses are recommended).*
- At present, Dexedrine® is approved for use in Army and Air Force combat aviation operations.
  - Army: http://usasam.amedd.army.mil/_AAMA/policyLetter.htm
  - Air Force: https://www.afms.mil/aeromed/docs/policy/2001/AircrewFatigue.pdf

Dexedrine maintains wakefulness in sustained operations

Flight Performance



Subjective Mood Disturbance

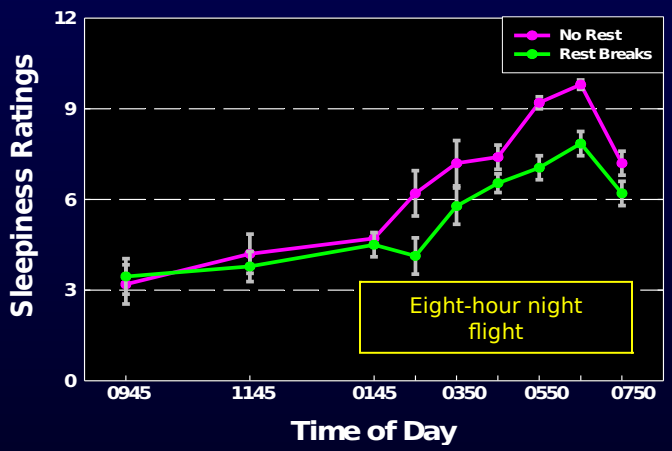


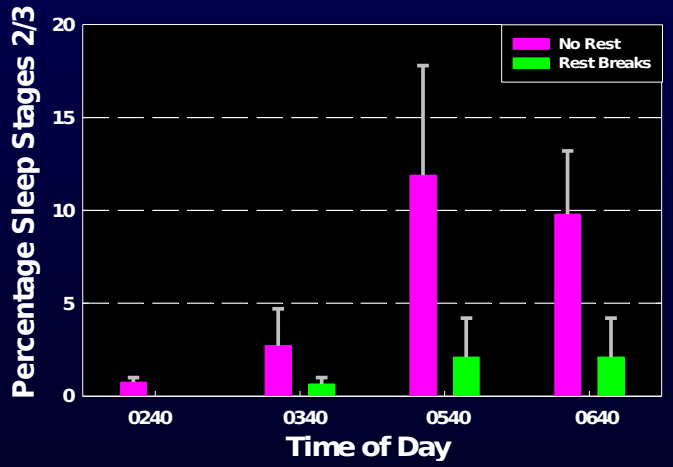
From Caldwell et al., 2000

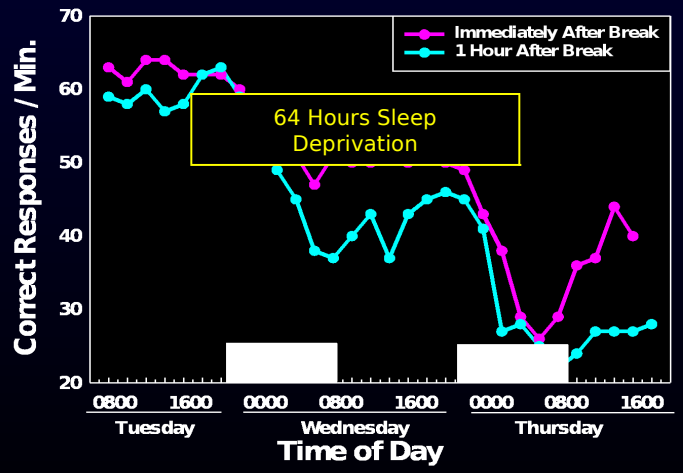
Properly-spaced rest breaks can help sustain performance

- Long bouts of work produce fatigue and boredom which can seriously impair performance.
  - Liberal rest breaks provide for physiological recovery, increased mental stimulation, and improved mood.
  - Studies have shown that work breaks improve productivity and reduce subjective sleepiness.
- Optimum schedules for breaks have not been determined.
- However, a break at least every 1-2 hours is recommended when possible.
- The more repetitious, boring, and tedious the task, the more frequently breaks should be scheduled.

Short breaks temporarily restore performance







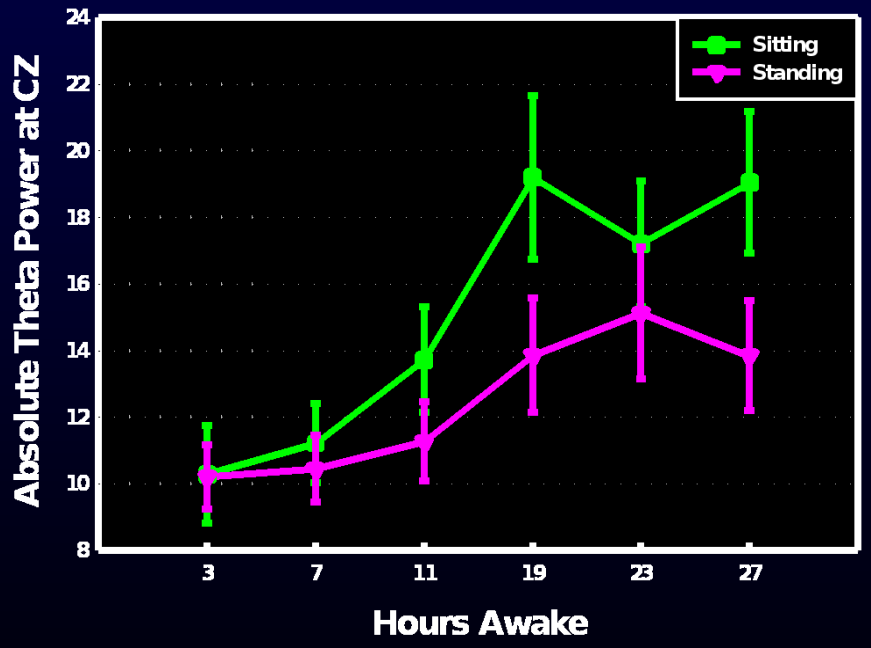
Pigeau et al., 1995; Neri et al., 2002

Body posture can influence the level of sleepiness

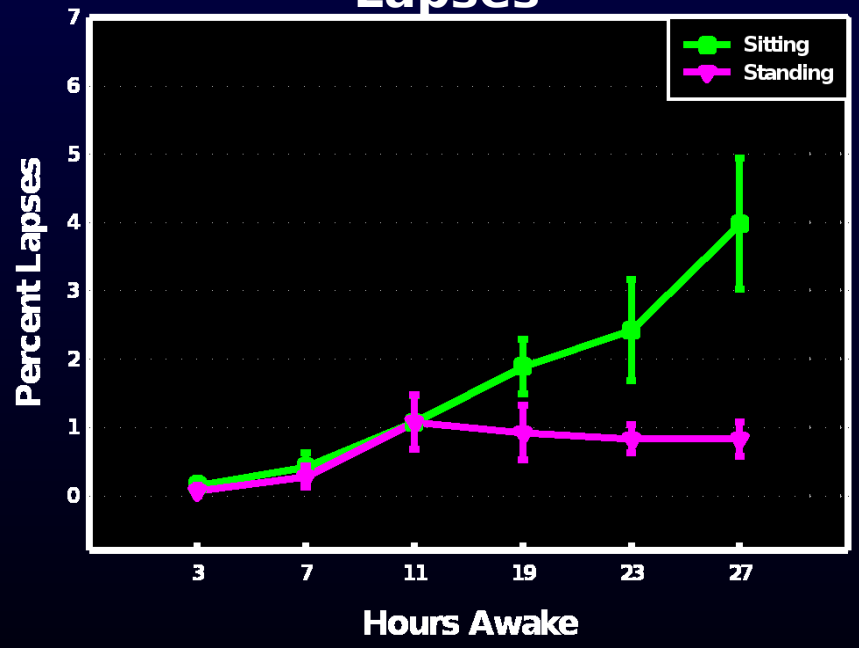
- In general, the more upright the body's position, the less sleepiness there will be.
  - Tilting people upright on a tilt-table causes higher-frequency brain activity than lying flat
  - The less people are allowed to recline in their seats, the less they are able to sleep
  - Narcolepsy patients report less sleepiness while standing than while sitting
- Research shows that physiological alertness and performance in sleep-deprived people is better when standing than when sitting.

An upright posture attenuates slow-wave EEG and reduces attention lapses

Slow-wave Brain Activity



Psychomotor Vigilance Lapses



Caldwell, Prazinko, and Caldwell, 2002

Exercise, cold air, and music don't really help

- **Some research shows that exercise can slightly improve alertness.**
  - **However, the effect is short-lived (maybe 20 minutes) and probably leads to more fatigue later.**
  - **Frequent exercise breaks aren't feasible in most aviation operations.**
- **"Cold air to the face" has not been proven to stave off fatigue.**
- **Listening to a radio *slightly* improves reaction time and decreases subjective sleepiness.**
  - **However, there is no evidence that it improves driving or other types of performance.**

Physical fitness is not a safeguard against mental fatigue

- The military has historically tried to decrease fatigue susceptibility by improving physical fitness.
- This strategy works well in jobs which require physical labor.
- However, it does not protect against mental fatigue.
  - One study showed fewer subjective complaints from night workers after physical training, but actual performance was not affected.
- Physical fitness may help you look better and live longer, but don’t depend on it to overcome fatigue!

Summary and conclusions

- Fatigue is a major contributor to accidents, lost productivity, and poor quality of life.
- As the operational tempo continues to increase, the potential for fatigue-related problems will only become more serious.
- However, safety, performance, and general operational readiness can be preserved by:
  - Adhering to good work-scheduling practices.
  - Implementing proven fatigue countermeasures.
  - Ensuring that off-duty personnel have sufficient sleep opportunities.
  - Making adequate daily sleep a top priority.
- Remember, sleep is a physical necessity--not a luxury, and there is NO substitute for SLEEP!

Fatigue Countermeasures Program

America's Air Force
Global Vigilance, Reach, and Power

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